

AMENDMENT AND RESPONSE

Serial Number: 08/818,289

Filing Date: March 14, 1997

Title: METHOD AND APPARATUS FOR OPTICAL INTERACTANCE AND TRANSMITTANCE MEASUREMENTS

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IN THE CLAIMS

- R₁
1. (CANCELLED)
 2. (DELETED EARLIER)
 3. (DELETED EARLIER)
 4. (DELETED EARLIER)
 5. (DELETED EARLIER)

1
& (PREVIOUSLY AMENDED) A method for improving optical interactance measurements comprising the steps of:

passing illumination along a plurality of different transmission paths through an interior portion of a material having a characteristic to be measured;

defining each of said paths by corresponding and separated surface areas on said material, one of said surface areas for passing illumination into said material and the second of said surface areas for passing transmitted illumination from said material for detection, at least one of said surface areas of each of said paths being extended in length at substantially constant spacing from the other surface area of said each of said paths, the total length of said extended surface area of said each of said paths being substantially greater than the distance separating said corresponding and separated surface areas defining said each of said paths;

providing optical directionality for radiation passing through at least one of said extended surface areas by orienting the optical axes at the respective probe surface area at an angle with respect to the surface of said material and generally towards the said corresponding and separated surface area on said material; sensing a plurality of independent signals developed at the same time or in rapid sequence representing optical

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information obtained from within said material in response to said illumination passing along said different paths, each independent signal corresponding to a particular path; and processing said signals in accordance with appropriate modeling techniques to determine qualitative or quantitative characteristics of the material.

7. (CANCELLED)

8. (DELETED EARLIER)

9. (DELETED EARLIER)

10. (DELETED EARLIER)

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²
~~N~~. (PREVIOUSLY AMENDED) Apparatus for improving optical interactance, transmittance and reflectance measurements comprising: an elongated probe having a body portion and a tip portion, the body portion comprising a central tubular element surrounded by an annular outer element; the tip portion having a central aperture which communicates with said central tubular element and a plurality of rings which communicate with said annular outer element; the rings in said tip portion being angled with respect to the longitudinal axis of the probe; a number of fiber optic bundles whose number corresponds to said plurality of rings being disposed within said outer element, each bundle being arranged at one end to exit at a respective ring and, at the other end, at least one such bundle being connected to a source of illumination; and optical means disposed in the central tubular element for receiving optical information resulting from applied illumination to a specimen from said central aperture from different paths through a specimen and for conveying said information to a sensing device so as to develop signals representing said specimen optical information.

³
~~N~~ (ORIGINAL) The apparatus of claim ²
~~N~~ wherein each fiber optic bundle is arranged at the other end to be connected to a source of illumination.

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13. (ORIGINAL) The apparatus of claim 11 also including means to process said signals in accordance with appropriate modeling techniques to minimize inaccuracies in spectroscopic determination of qualitative or quantitative characteristics of the specimen.

5

14. (ORIGINAL) The apparatus of claim 11 wherein said tip portion and fiber optic elements at the tip portion are angled at approximately 26E with respect to the longitudinal axis of the probe.

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15. (ORIGINAL) The apparatus of claim 11 including at least one lens disposed in said central tubular element for focusing the optical information received in said central aperture and means responsive to the focused information for forming a signal representing said information.

16. (DELETED EARLIER)

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17. (ORIGINAL) The apparatus of claim 15 wherein said means responsive to the focused information includes a fiber optic element for conveying the focused optical information to a detector responsive to the optical information conveyed by the fiber optic element.

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18. (ORIGINAL) The apparatus of claim 11 also including fiber optic means and a detector for providing a signal representative of the illumination received by the specimen.

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19. (ORIGINAL) The apparatus of claim 15 including means for allowing the focusing of said lenses to be changed.

20. (DELETED EARLIER)

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21. (DELETED EARLIER)

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~~22~~. (AMENDED PREVIOUSLY) In a method of using apparatus for improving optical transmittance and reflectance measurements comprising means for providing illumination to a specimen having a characteristic to be measured along a plurality of different paths, at a probe tip of said apparatus, means for sensing optical information, at a central aperture of said probe tip, developed by said illumination provided from an illuminated specimen, means, responsive to said sensed optical information, for developing a plurality of independent signals corresponding in number to said plurality of paths, said signals representing said optical information obtained from said specimen, and means for processing said signals in accordance with appropriate modeling techniques to minimize inaccuracies in spectroscopic determination of quantitative or qualitative characteristics of the specimen, said method including the step of providing a further source of illumination, arranging said probe tip adjacent a near side of a specimen of small size, arranging the further source of illumination on a far side of said specimen, and using said probe tip so that reflected energy from said specimen is directed to said central aperture and/or energy transmitted by said further source through said specimen is directed to said central aperture.

¹¹
~~23~~. (AMENDED PREVIOUSLY) In a method as in claim ¹⁰~~22~~ including the step of selectively choosing an operational mode of reflectance, transmittance or combined reflectance and transmittance by selectively applying said illumination and selectively sensing reflected or transmitted illumination.

¹²
~~24~~. (AMENDED PREVIOUSLY) In a method of using apparatus for improving optical transmittance and reflectance measurements comprising means for providing illumination to a specimen having a characteristic to be measured along a plurality of different paths at a probe tip of said apparatus, means for sensing optical information, at a central aperture of said probe tip, developed by said illumination provided from an

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illuminated specimen, means, responsive to said sensed optical information, for developing a plurality of independent signals corresponding in number to said plurality of paths, said signals representing said optical information obtained from said specimen, and means for processing said signals in accordance with appropriate modeling techniques to minimize inaccuracies in spectroscopic determination of quantitative or qualitative characteristics of the specimen, said method including the steps of providing a further detector for developing an electrical signal responsive to illumination, arranging said probe tip adjacent a near side of a specimen of small size, arranging said further detector on a far side of said specimen, and using said probe tip so that reflected energy from said specimen is directed to said central aperture and/or energy transmitted by said probe is detected by said further detector.

¹³
~~26~~. (AMENDED PREVIOUSLY) In a method as in claim ¹²~~24~~ including the step of selectively choosing an operational mode of reflectance, transmittance or combined reflectance and transmittance by selectively applying said illumination and selectively sensing reflected or transmitted illumination.

R, ¹⁴
~~26~~. (AMENDED PREVIOUSLY) Apparatus for improving optical interactance, and transmittance measurements comprising: an elongated probe having a body portion and a tip portion, the body portion comprising a central tubular element surrounded by an annular outer element; the tip portion having a central aperture which communicates with said central tubular element and a plurality of rings which communicate with said annular outer element; a plurality of fiber optic bundles whose number corresponds to said plurality of rings being disposed within said outer element, each bundle being arranged annularly within a respective ring at said tip end for receiving optical information from within a particular material and, at the other end, each bundle being adapted to be connected to a detector for developing an independent signal corresponding to an illumination path through said material; and said central tubular element containing optical elements connected with a source of illumination, which illumination will exit at the central aperture.

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27. (DELETED EARLIER)

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30. (DELETED EARLIER)

31. (DELETED EARLIER)

32. (DELETED EARLIER)

33. (CANCELLED)

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34. (CURRENTLY AMENDED) ~~The method of claim 1~~ A process for improving optical interactance measurements comprising the steps of:

passing illumination along a plurality of different transmission paths through an interior portion of a material having a characteristic to be measured;
defining each of said transmission paths by corresponding and separated surface areas on said material, one of said corresponding and separated surface areas for passing transmitted illumination into said material as a beginning of a first transmission path and a second of said corresponding and separated surface areas for passing transmitted illumination from said material for detection as an end of the first transmission path, at least one of said corresponding and separated surface areas of each of said transmission paths being extended in length as a ring shape or slit shape on said surface at substantially constant spacing from the other corresponding and separated surface area of said each of said paths, the total length of said ring or slit surface area of said each of said transmission paths

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being substantially greater than the mean distance separating said corresponding and separated surface areas defining each of said transmission paths;

sensing a plurality of independent signals developed at the same time or in rapid sequence representing optical information obtained from a spectrum related to analytes and interferences within said material in response to said illumination passing along different transmission paths, each signal corresponding to a particular transmission path; and

processing and combining said signals in accordance with appropriate chemometric modeling techniques and determination of model parameters during the calibration process to determine qualitative characteristics of the material, including the step of defining at least one of said paths and said surface areas by areas on opposite surfaces of said material.

R 1 35. (PREVIOUSLY AMENDED) A method for improving optical interactance measurements comprising the steps of: passing illumination along a plurality of different paths through an interior portion of a material having a characteristic to be measured; defining each of said paths by corresponding and separated surface areas on said material, at least one of said surface areas of one of said paths being extended in length at substantially constant spacing from the other surface area of said one path; sensing a plurality of independent signals developed at the same time or in rapid sequence representing optical information obtained from within said material in response to said illumination passing along said different paths, each independent signal corresponding to a particular path; and processing said signals in accordance with appropriate modeling techniques to determine qualitative or quantitative characteristics of the material; wherein said steps of passing illumination and sensing are provided by an instrument for said interactance measurement and said method further includes the steps of moving said instrument a predetermined distance away from said material and performing a reflectance measurement of said material.

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36. (CANCELLED)

37. (CANCELLED)

38. (CANCELLED)

39. (CANCELLED)

40. (CANCELLED)

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41. (PRESENTLY AMENDED) Apparatus for optical interactance measurements of an interior portion of a material, said measurements being effected by passing illumination through portions of the material comprising: apertures for defining corresponding and separated surface areas on said material for defining each of a plurality of transmission paths through an interior portion of said material, one of said corresponding and separated surface areas for passing illumination into said material as beginning of a first transmission path and the second of said corresponding and separated surface areas for passing illumination from said material for detection as an end of the first transmission path, at least one of said corresponding and separated surface areas of each of said transmission paths being extended in length as a ring shape or slit shape on said surface and substantially constantly spaced from its corresponding surface area, the total length of said [extended surface] ring shape or slit shape area of each of said transmission paths being substantially greater than the mean distance separating said corresponding and separated surface areas defining said each of said transmission paths;
illuminator for directing illumination onto said illumination surface areas and along said transmission paths;

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sensor for sensing optical information indicative of said interior portion of said material developed by illumination passing along said transmission paths to said detection surface areas of said transmission paths;

signaler responsive to said sensing means, for developing a plurality of independent signals corresponding in number to said plurality of transmission paths, each of said signals representing said optical information obtained in a spectrum related to analytes and interferences within said material; and

processor for combining and processing said signals in accordance with appropriate chemometric modeling techniques and determination of model parameters during the calibration process to determine quantitative or qualitative characteristics of said material,

wherein said aperture means are operative to define one surface area of at least two of said paths to be common to said two paths, and ~~The apparatus of claim 39~~
wherein said aperture means are operative to define said common surface areas as the detection surface area.

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~~42.~~ (CURRENTLY AMENDED) Apparatus for optical interactance

measurements of an interior portion of a material, said measurements being effected by passing illumination through portions of the material comprising:

apertures for defining corresponding and separated surface areas on said material for defining each of a plurality of transmission paths through an interior portion of said material, one of said corresponding and separated surface areas for passing illumination into said material as beginning of a first transmission path and the second of said corresponding and separated surface areas for passing illumination from said material for detection as an end of the first transmission path, at least one of said corresponding and separated surface areas of each of said transmission paths being extended in length as a ring shape or slit shape on said surface and substantially constantly spaced from its corresponding surface area, the total length of said [extended surface] ring shape or slit shape area of each of said transmission paths being substantially greater than the mean distance

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separating said corresponding and separated surface areas defining said each of said transmission paths;

illuminator for directing illumination onto said illumination surface areas and along said transmission paths;

sensor for sensing optical information indicative of said interior portion of said material developed by illumination passing along said transmission paths to said detection surface areas of said transmission paths;

signaler responsive to said sensing means, for developing a plurality of independent signals corresponding in number to said plurality of transmission paths, each of said signals representing said optical information obtained in a spectrum related to analytes and interferences within said material; and

processor for combining and processing said signals in accordance with appropriate chemometric modeling techniques and determination of model parameters during the calibration process to determine quantitative or qualitative characteristics of said material. The apparatus of claim 7 or claim 36 wherein said aperture means are operative to define said illumination and sensing areas for at least one of said paths to be on opposite surfaces of said material.

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43. (PREVIOUSLY AMENDED) A method for effecting optical interactance and reflectance measurements relative to a material, having a characteristic to be measured, comprising the steps of:

providing optical means, at a first predetermined distance from a surface of said material, for defining on said material at least one illumination surface area and at least one detection surface area which are separated said surface areas on said material defining at least one transmission path through an interior portion of said material for performing interactance measurements, at least one of said surface areas of one of said paths being extended in length at substantially constant spacing from the other surface of said one path;

providing said optical means at a second predetermined distance, relative to the surface of said material, for defining illumination and detection surface areas on

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said material which are at least partially superimposed thereby defining a surface area on said material for performing diffuse reflectance measurements;

illuminating said illumination area and detecting optical information received from said detection area for developing signals representing said optical information obtained from said material in response to said illumination; and

processing said signals detected by said optical means in accordance with appropriate modeling techniques to determine quantitative or qualitative characteristics of the material.

R1 44. (EARLIER DELETED)

21 45. (PREVIOUSLY AMENDED) The method as in claim 43 wherein said 20 optical means, at said first distance, defines a plurality of distinct illumination surface areas and at least one detection surface area, whereby a plurality of different transmission paths are defined in said specimen.

46. (PREVIOUSLY AMENDED) The method as in claim 45 wherein said optical means, at said first distance, defines at least one of said illumination surface areas as extended in length.

47. (PREVIOUSLY AMENDED) The method as in claim 45 wherein said optical means, at said first distance, defines said at least one detection surface area as extended in length.

48. (PREVIOUSLY AMENDED) The method as in claim 43 wherein said optical means, at said first distance, defines at least one of said illumination surface areas and said at least one detection surface areas as extended and parallel.

49. (PREVIOUSLY AMENDED) The method as in claim 43 wherein said optical means, at said first distance, defines at least one of said surface areas to be extended and

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to define another of said surface areas to be distinct and contained within the boundary defined by said extended surface area.

50. (PREVIOUSLY AMENDED) The method as in claim 43 wherein said optical means, at said first distance, defines said illumination and detection surface areas to be parallel.

22 46. (PREVIOUSLY AMENDED) The method as in claim 45 wherein said optical means, at said first distance, defines at least one of said illumination surface areas as a ring shape or slit shape.

23 47. (PREVIOUSLY AMENDED) The method as in claim 45 wherein said optical means, at said first distance, defines said at least one detection surface area as extended in length as a ring shape or slit shape.

24 48. (PREVIOUSLY AMENDED) The method as in claim 43 wherein said optical means, at said first distance, defines at least one of said illumination surface areas and said at least one detection areas as parallel ring shapes or slit shapes.

RL 25 49. (PREVIOUSLY AMENDED) The method as in claim 48 wherein said optical means, at said first distance, defines at least one of said surface areas to be extended as a ring shape or slit shape and to define another of said surface areas to be distinct and contained within a boundary defined by said ring shape or slit shape surface area.

26 50. (PREVIOUSLY AMENDED) The method as in claim 43 wherein said optical means, at said first distance, defines said illumination and detection surface areas to be parallel.

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²¹ 1. (PREVIOUSLY AMENDED) The method as in claim ²⁰ 43 wherein said optical means, at said first distance, defines said illumination and detection surface areas to be concentric.

²⁶ 2. (PREVIOUSLY AMENDED) The method as in claim ²⁰ 43 wherein said optical means, at a plurality of said second distances, defines a plurality of illumination and detection surface areas which are at least partially superimposed corresponding to said plurality of said second distances.

¹³ 3. (ORIGINAL) The apparatus of claim ¹⁴ 26, wherein said rings in said tip portion are angled with respect to the longitudinal axis of the probe.

54. (PREVIOUSLY CANCELLED)

55. (PREVIOUSLY CANCELLED)

²⁹ 56. (PREVIOUSLY ADDED) A method for improving optical interactance measurements of a material comprising the steps of: (a) passing illumination along a plurality of different paths through an interior portion of a material having a characteristic to be measured; (b) said different paths of illumination each comprising a distribution of substantially equidistant illumination means surrounding a central detection aperture; (c) said central detection aperture comprising optical connections within said central detection aperture which are connected to a detection system; (d) sensing in said detection system a plurality of independent signals developed at the same time or in rapid sequence representing optical information obtained from within said material in response to said illumination passing along said different paths, each independent signal corresponding to a particular path; and (e) processing said signals in accordance with modeling techniques to determine qualitative or quantitative characteristics of the material.

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57. (PREVIOUSLY ADDED) The process of claim 36 wherein said central detection aperture consists of optical connections within said central detection aperture,

38. (PREVIOUSLY ADDED) The process of claim 57 wherein said optical connections within said central aperture comprises fiber optics.

39. (PREVIOUSLY ADDED) The process of claim 37 wherein said distribution of substantially equidistant illumination means comprises a circular distribution of illumination means.

40. (PREVIOUSLY ADDED) The process of claim 37 wherein substantially equidistant illumination means comprise fiber optics.

41. (PREVIOUSLY ADDED) The process of claim 39 wherein substantially equidistant illumination means comprise fiber optics.

42. (PREVIOUSLY ADDED) The process of claim 41 wherein said fiber optics within each circular distribution of illumination means are within individual ring apertures surrounding a central detection aperture and are present within an aperture which is sloped towards said central detection aperture.

43. (PREVIOUSLY ADDED) The process of claim 37 wherein fiber optics within individual ring apertures surrounding a central detection aperture are within apertures which are concentrically spaced around said central detection aperture.

44. (PREVIOUSLY ADDED) The process of claim 41 wherein said fiber optics within individual ring apertures surrounding a central detection aperture are present within an aperture which is sloped towards said central detection aperture.

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³⁹ 65. (PREVIOUSLY ADDED) Apparatus for improving optical interactance, transmittance and reflectance measurements comprising:

- (a) a probe comprising a body portion and a contacting portion;
- (b) said contacting portion comprising: (i) a central detection area comprising at least one optical connection to a detection system; and (ii) at least two outer illumination areas, each outer illumination area being connected to illumination means;
- (c) said at least two outer illumination areas being optically connected to at least one source of illumination which can provide different signals at the same time or in rapid sequence to each of said at least two outer illumination areas;
- (d) said at least two outer illumination areas and said central detection area forming at least two different paths of illumination between said at least two illumination areas and said central detection area, said different paths of illumination each comprising a distribution of substantially equidistant illumination means surrounding said central detection area.

⁴⁰ 66. (PREVIOUSLY ADDED) The apparatus of claim ³⁹ 65 wherein said central detection area consists of optical connections to a detector system.

⁴¹ 67. (PREVIOUSLY ADDED) The apparatus of claim ⁴⁰ 66 wherein said optical connection of said central detection area to said detection system comprises fiber optics.

⁴⁴ 68. (PREVIOUSLY ADDED) The apparatus of claim ⁴⁰ 66 wherein said optical connection of said at least two illumination areas and said at least one source of illumination comprises fiber optics.

⁴² 69. (PREVIOUSLY ADDED) The apparatus of claim ⁴¹ 67 wherein said optical connection of said at least two illumination areas and said at least one source of illumination comprises fiber optics.

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43
70. (PREVIOUSLY ADDED) The apparatus of claim 67 wherein said central
detection area consists of optical fibers which consist of a detection system.

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71. (PREVIOUSLY ADDED) The process of claim 31 wherein said central
detection aperture consists of fiber optics which consist of a detection system.

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72. (PREVIOUSLY ADDED) A method for improving optical interactance
measurements comprising the steps of:

passing illumination along at least one transmission path through an
interior portion of a material having a characteristic to be measured, said material
having a surface;

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defining said at least one path by transmission path optically
transmissively connecting corresponding and separated surface areas on said
surface of said material, one of said surface areas optically transmissively
connected to a first of said corresponding and separated areas for passing
illumination into said material and the second of said surface areas optically
transmissively connected to a second of said corresponding and separated areas
for passing transmitted illumination from said material for detection, at least one
of said surface areas of said at least one path having a dimension with a total
length being extended in length at substantially constant spacing from a similar
dimension of the other surface area of said at least one path, the total length of
said extended surface area of said at least one path being substantially greater than
the distance separating said corresponding and separated surface areas defining
said at least one path;

providing optical directionality for radiation passing through at least one
of said extended surface areas by orienting the optical axes at the respective probe
surface area at an angle with respect to the surface of said material and generally
towards the said corresponding and separated surface area on said material;

sensing a plurality of independent signals developed at the same time or in
rapid sequence representing optical information obtained from within said

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material in response to said illumination passing along said at least one path, each independent signal corresponding to a particular path, and
processing said signals in accordance with appropriate modeling techniques to determine qualitative or quantitative characteristics of the material.

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